Ministry
of
Transportation
Ontario

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A REVIEW OF MTO CONCRETE COMPRESSIVE STRENGTH DATA FOR 1988

MATERIALS INFORMATION
ENGINEERING MATERIALS OFFICE

A REVIEW OF MTO CONCRETE COMPRESSIVE STRENGTH DATA FOR 1988

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INTRODUCTION

Copies of the 28-day compressive strength tests from throughout the Province are forwarded to the Concrete Section of the Engineering Materials Office in Downsview. The results are reviewed and placed on a microcomputer to provide contract, regional and provincial summaries. Most concrete placed on Ministry contracts must meet the requirements of OPSS 1350 in the Ontario Provincial Standard Specifications. One of the requirements of acceptance is based on the results of 28-day compressive strength tests as specified in Section 1350.08.01.05 of the specifications.

This report provides a summary and review of 28-day compressive strength test results from the 1988 contracts throughout Ontario involving concrete work. The summary includes test results of all concrete classes from 15 MPa to 35 MPa including latex modified concrete. Not included in the report are results on concrete placed on maintenance and municipal contracts or tremie concrete. Only the test results from concrete placed in 1988 are included in the report.

A new concrete performance specification has been in place on a trial basis for several years and used on selected contracts. Under this specification concrete is accepted based on a statistical analysis of the mean and standard deviation of all acceptance cylinders in a particular lot. A summary of the acceptance cylinder results for concrete placed in 1988 under this specification is contained in this report.

RESULTS

OPSS 1350 states that a test is defined as the average of two standard 150 mm x 300 mm cylinders. For this report the term "pass" indicates that the result of a single 28-day compressive test (average of 2 standard cylinders) is greater than or equal to the specified strength. The term "fail" indicates that the result of a single 28-day compressive strength test are less than the specified strength. Table A shows the total number of tests performed in each of the five regions as well as the percentage of tests that passed and failed. In Table B the tests in each region are broken down by concrete class including concrete containing slag cement and latex modified concrete.

Figures 1 - 9 provide a graphical summary of test results by concrete class and type. The figures show the mean and the standard deviation of all test results by contract for each concrete class in the five regions. Actual contract numbers in each region have been replaced with a series of numbers beginning at 1. Contracts that contain less than two results for a given concrete class are not shown in these figures. Also not shown in these figures is the 15 MPa class concrete. Appendix A contains the statistics for all test results throughout the Province in tabular form including a list of contracts under the performance specifications.

Figure 1 presents the test results for 20 MPa class concrete containing no slag cement. Good compressive strengths were achieved with this class of concrete in all regions.

TABLE A SUMMARY OF TESTS BY REGION

REGION	NUMBER OF TESTS	% PASS	% FAIL
CENTRAL	1146	93.2	6.8
SOUTHWESTERN	600	91.7	8.3
EASTERN	585	91.8	8.2
NORTHWESTERN	224	85.3	14.7
NORTHERN	332	88.9	11.1
ALL REGIONS	2887	91.5	8.5
ALL REGIONS (Under performance Specification)	643	93.3	6.7
ALL REGIONS (Without performance Specification)	2244	91.0	9.0

TABLE B SUMMARY OF TESTS BY REGION (NON-SLAG CEMENT,SLAG CEMENT,LATEX MODIFIED CONCRETE)

REGION	15 MPa		20 MPa		20 MPa SLAG		25 MPa		25 MPa SLAG	
	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS
CENTRAL REGION			20	100	44	97.7	8	75.0	113	96.5
SOUTH-WESTERN REGION	12	100	60	100	1	100	68	97.1	46	97.8
EASTERN REGION			14	100	22	100	57	93.0	85	97.6
NORTH-WESTERN REGION			28	100			44	100	4	100
NORTHERN REGION			6	100	6	100	65	98.5	5	100
ALL REGIONS	12	100	128	100	73	98.6	242	96.3	253	97.2

REGION	30 MPa		30 MPa SLAG		30 MPa LATEX		35 MPa		35 MPa SLAG	
	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS
CENTRAL REGION	212	87.7	605	94.9	46	97.8	35	85.7	63	100
SOUTH-WESTERN REGION	237	916	74	87.9	1	100	19	89.5	82	80.5
EASTERN REGION	56	92.9	334	88.6			17	100		
NORTH-WESTERN REGION	148	77.7								
NORTHERN REGION	191	82.7	35	94.3					24	95.8
ALL REGIONS	844	85.3	1048	92.4	47	97.9	71	90.1	169	89.9

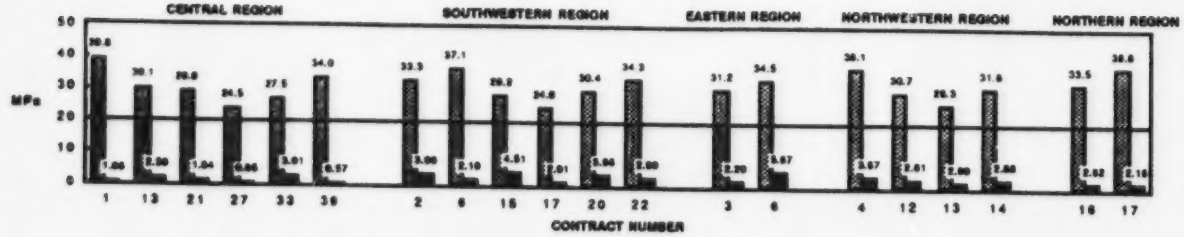

FIGURE 1 SUMMARY OF TESTS BY CONTRACT - 20 MPa NON-SLAG CEMENT

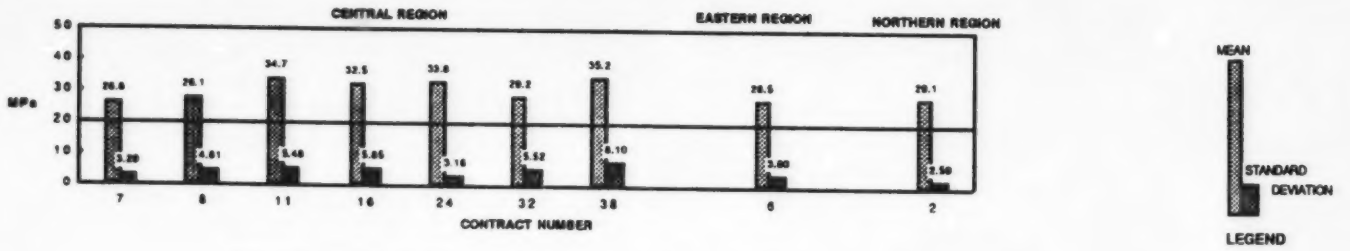

FIGURE 2 SUMMARY OF TESTS BY CONTRACT - 20 MPa SLAG CEMENT

Figure 2 summarizes test results for 20 MPa class concrete containing slag cement. This class of concrete was used in all regions except Northwestern Region. In Central Region 1 test out of 44 tests failed to meet the specified strength. No failures occurred in the other regions.

Figure 3 contains the summary of test results for 25 MPa class concrete containing no slag cement. All regions except Northwestern Region experienced some difficulty with this class of concrete. Central Region had 2 failures out of 8 tests. Southwestern Region had 2 tests fail out of 68 tests, while in Eastern Region 4 tests out of 57 tests failed to meet the specified strength. Out of 65 tests only 1 failed to meet the required strength in Northern Region.

The summary of test results for the 25 MPa class concrete containing slag cement are present in Figure 4. Northwestern and Northern Regions had no problems in achieving good compressive strengths. Minor difficulties were encountered in the other regions. Four tests failed to meet the specified strength out of 113 tests in Central Region. Southwestern Region had 1 failure out of 46 tests, while Eastern Region had 2 failures out of 85 tests.

Figure 5 presents the test results for 30 MPa class concrete containing no slag cement. All regions experienced difficulties with this class of concrete. Out of 844 tests, 14.7 per cent failed to meet the required specified strength.

Figure 6 contains the test results for 30 MPa latex modified concrete. Only 2 regions used this type of concrete in 1988, Central Region and Southwestern Region. Problems were encountered in achieving acceptable compressive strengths only in Central Region where 8 tests out of a total of 46 tests failed.

The test results for 30 MPa class concrete containing slag cement are present in Figure 7. All regions except Northwestern Region used this class of concrete. Difficulties with this class of concrete were encountered by all the regions. The means range from a low of 28.0 MPa up to a high of 42.8 MPa. Out of 1,048 tests, 80 tests failed to meet the required strength.

Figure 8 presents a summary of results of 35 MPa class concrete, both non-slag and slag mixes. The 35 MPa class concrete without slag cement was used by Central Region, Southwestern Region and Eastern Region. While no difficulties were encountered by Eastern Region, Central Region had 5 test failures out of 35 tests and Southwestern Region had 2 test failures out of 19 tests.

Of the three regions (Central, Southwestern and Northern) that used the 35 MPa class concrete with slag cement, only Central Region had no test failures. Out of 82 tests, 19.5 per cent failed to meet the required strength in Southwestern Region. In Northern Region 1 test failed to meet the specified strength requirement out of 24 tests.

A graphical representation of mean and standard deviation for contracts which were under the concrete performance specification is shown in Figure 9. Only the test results which were used for acceptance purposes are included. (These

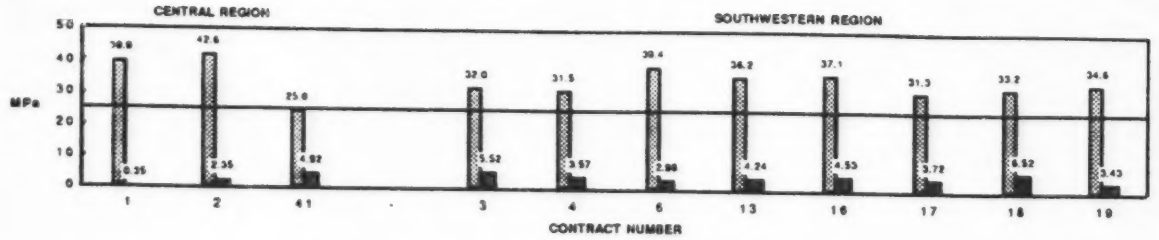

FIGURE 3 SUMMARY OF TESTS BY CONTRACT - 25 MPa NON-SLAG CEMENT

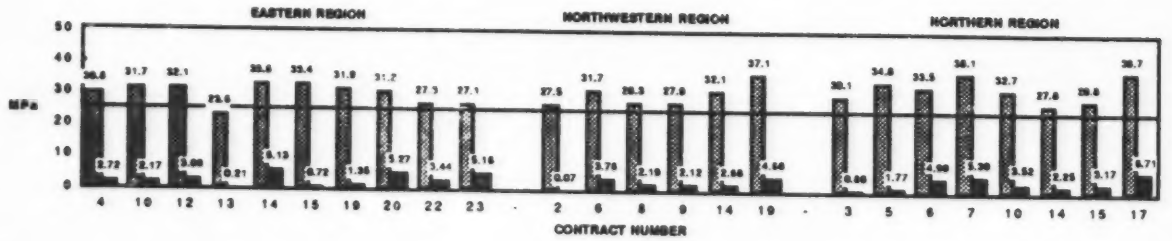

FIGURE 3 SUMMARY OF TESTS BY CONTRACT - 25 MPa NON-SLAG CEMENT

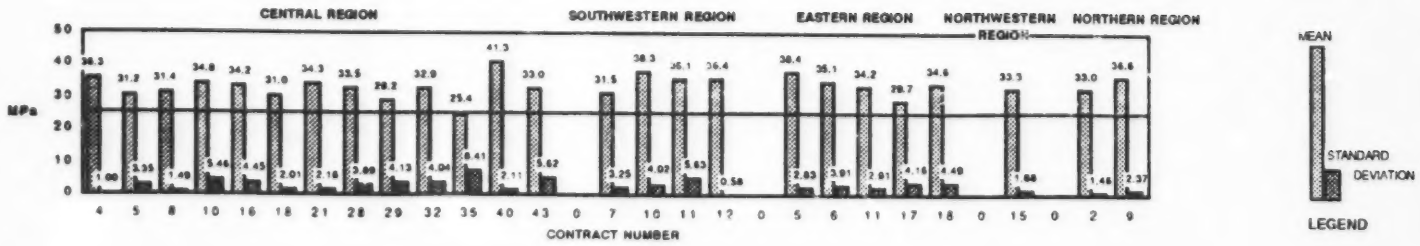

FIGURE 4 SUMMARY OF TESTS BY CONTRACT - 25 MPa SLAG CEMENT

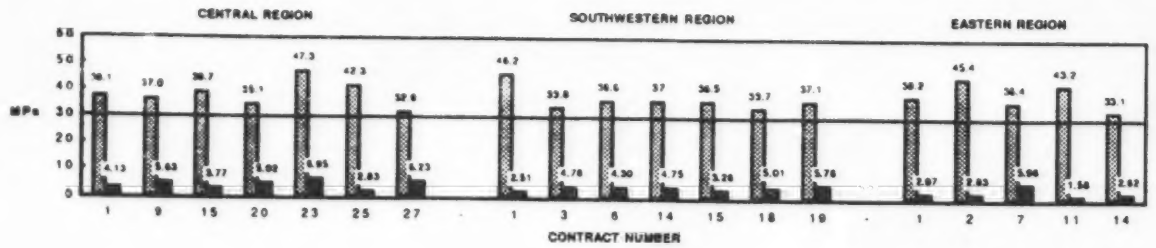

FIGURE 5 SUMMARY OF TESTS BY CONTRACT - 30 MPa NON-SLAG CEMENT

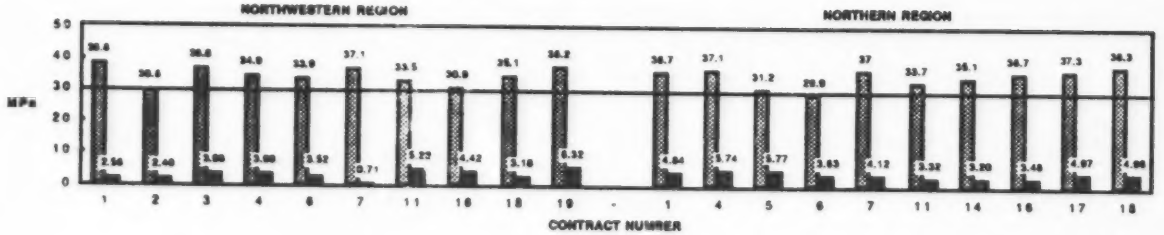

FIGURE 5 SUMMARY OF TESTS BY CONTRACT - 30 MPa NON-SLAG CEMENT

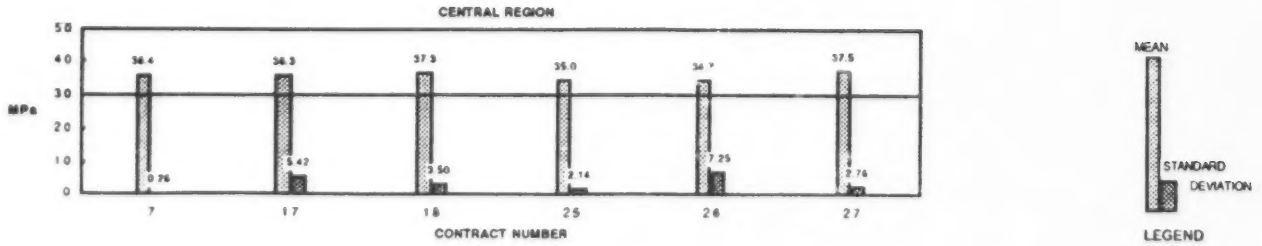

FIGURE 6 SUMMARY OF TESTS BY CONTRACT - 30 MPa LATEX MODIFIED CONCRETE

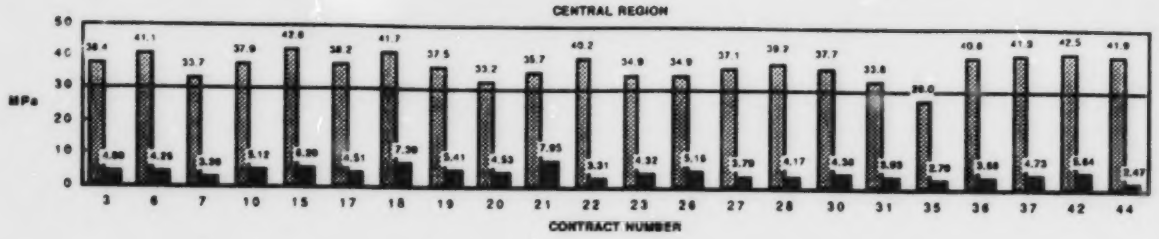

FIGURE 7 SUMMARY OF TESTS BY CONTRACT - 30 MPa SLAG CEMENT

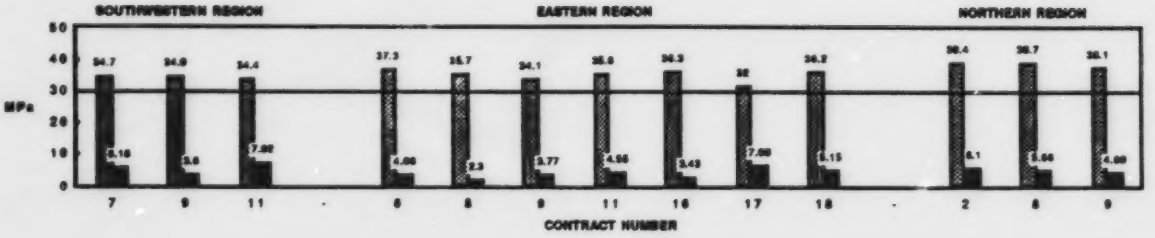

FIGURE 7 SUMMARY OF TESTS BY CONTRACT - 30 MPa SLAG CEMENT

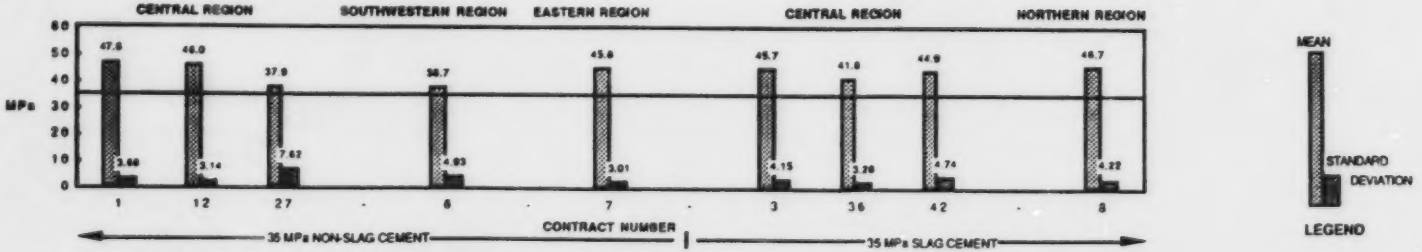

FIGURE 8 SUMMARY OF TESTS BY CONTRACT - 35 MPa NON-SLAG CEMENT & 35 MPa SLAG CEMENT

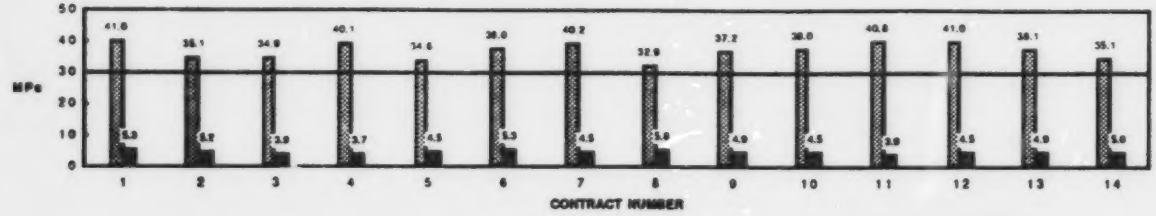

FIGURE 8 SUMMARY OF TESTS BY CONTRACT UNDER THE PERFORMANCE SPECIFICATION (30 MPa CONCRETE)

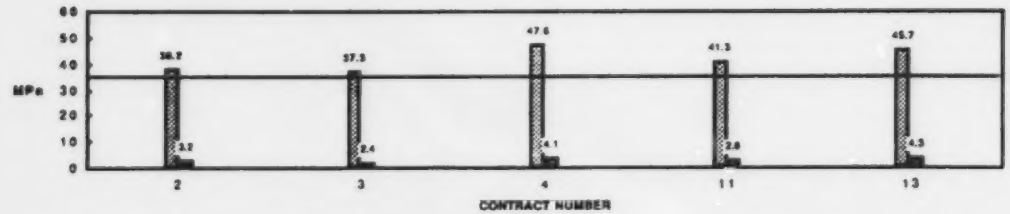

FIGURE 9 SUMMARY OF TESTS BY CONTRACT UNDER THE PERFORMANCE SPECIFICATION (35 MPa CONCRETE)

results are also included in the overall summaries). All results for a class of concrete were combined for each contract irrespective of the actual number of lots of that type.

Mean strengths for the 30 MPa concrete ranged from 32.9 to 41.0 MPa and the standard deviation ranged from 3.7 to 5.8 MPa. Mean strengths for the 35 MPa concrete ranged from 37.3 to 47.6 MPa and the standard deviation ranged from 2.4 to 4.3 MPa.

SUMMARY

1. Good compressive strengths were achieved with the 15 MPa and 20 MPa class concrete with or without slag cement.

2. All regions except Northwestern Region experienced low compressive strengths with the 25 MPa class concrete with and without slag cement. No difficulties were encountered with the 25 MPa class concrete with slag cement in Northern Region.

3. Low compressive strengths were most evident in 30 MPa class concrete with and without slag cement in all regions.

4. Some difficulties with the compressive strengths were encountered by Central Region with the latex modified concrete.

5. Eastern Region achieved good compressive strengths with the 35 MPa class concrete without slag cement. No problems were encountered in achieving good compressive strength in Central Region with the 35 MPa class concrete with slag cement.

6. 2,887 tests were carried out in 1988 of which 91.5 per cent were greater or equal to the required strength. Under the performance specification 93.3 per cent out of 643 tests met the required strength.

7. The average mean and standard deviation of the concrete under performance specification varied slightly from the average mean and standard deviation of the overall concrete.

8. Although there are considerably fewer tests under the performance specification the results are generally more favourable.

APPENDIX A

CENTRAL REGION

CON-TRACT	20 MPa			20 MPa SLAG			25 MPa			25 MPa SLAG			30MPa			30 MPa SLAG			30 MPa LATEX MOD.			35 MPa			35 MPa SLAG		
	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	#TESTS	MEAN	ST.DEV	#TESTS	MEAN	ST.DEV
1	3	39.8	1.06				2	39.9	0.35				8	38.1	4.13							5	47.6	3.68			
2							3	42.6	2.35																		
3																26	38.4	4.80							35	45.7	4.15
4										3	36.3	1.00															
5										4	31.2	3.35				1	37.2	-									
6																29	41.1	4.26									
7				2	26.8	3.29										11	33.7	3.39	3	36.4	0.26						
8				3	28.1	4.81				3	31.4	1.49															
9													56	37.0	5.63												
10										8	34.8	5.46				8	37.9	5.12									
11				5	34.7	5.48																					
12																											
13	3	30.1	2.59										1	27.0	-							14	46.0	3.14			
14													1	26.3	-												
15													54	39.7	3.77	14	42.8	6.20							1	36.2	
16				22	32.5	5.85				6	34.2	4.45															
17																17	38.2	4.51	12	36.3	5.42						
18										8	31.0	2.01				11	41.7	7.39	20	37.3	3.50						
19																11	37.5	5.41	1	38.5	-						
20													15	35.1	5.02	27	33.2	4.53									
21	3	29.9	1.84							3	34.3	2.16				45	35.7	7.95									
22																11	40.2	3.31									
23													4	47.3	6.95	20	34.9	4.32									
24				4	33.8	3.16																					
25													2	42.3	2.83				6	35.0	2.14						
26				1	24.0	-										78	34.9	5.16	2	34.7	7.25				1	38.9	-
27	2	24.5	0.85										70	32.6	6.23	25	37.1	3.79	2	37.5	2.76	16	37.9	7.62			
28										3	33.5	3.89				14	39.2	4.17							1	49.5	-
29										17	29.2	4.13															
30																205	37.7	4.38									
31																5	33.8	3.93									
32				2	29.2	5.52				42	32.9	4.04															
33	2	27.5	3.01																								
34													1	35.1	-												
35										2	25.4	8.41				4	28.0	2.70									
36																23	40.8	3.68							20	41.8	3.23
37																4	41.9	4.73									
38				5	35.2	8.10																					
39	7	34.0	0.57																								
40										8	41.3	2.11															
41							3	25.0	4.92																		
42																13	42.5	5.64									
43										6	33.0	5.62													5	44.9	4.74
44																3	41.9	2.47									

SUMMARY OF 28-DAY COMPRESSIVE STRENGTH TEST RESULTS

SOUTHWESTERN REGION

CON-TRACT	15 MPa			20 MPa			20 MPa SLAG			25 MPa			25 MPa SLAG			30 MPa			30 MPa SLAG			30 MPa LATEX MOD.			35 MPa		
	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV
1																2	46.2	2.51									
2				7	33.3	3.96																					
3	12	30.7	5.81							3	32.0	5.52				55	33.8	4.78									
4										19	31.5	3.57															
5										1	27.6	-															
6				9	37.1	2.10				12	39.4	2.98				25	36.6	4.30							19	38.7	4.93
7													19	31.5	3.25				40	34.7	6.18						
8													1	34.3	-				1	39.5	-						
9																			31	34.9	3.60						
10													12	38.3	4.02												
11							1	43.6	-				10	36.1	5.63				2	34.4	7.92						
12													4	36.4	0.58												
13										2	36.2	4.24															
14																124	37.0	4.75									
15				16	29.2	4.51										11	36.5	3.28									
16										12	37.1	4.53															
17				12	24.9	2.01				5	31.3	3.72				1	34.8	-									
18										9	33.2	6.52				4	33.7	5.01									
19										4	34.6	3.43				14	37.1	5.76				1	37.2	-			
20				4	30.4	3.66																					
21																1	36.0	-									
22				12	34.3	2.90																					
23										1	25.9	-															

SUMMARY OF 28-DAY COMPRESSIVE STRENGTH TEST RESULTS

EASTERN REGION

CON-TRACT	20 MPa			20 MPa SLAG			25 MPa			25 MPa SLAG			30 MPa			30 MPa SLAG			35 MPa		
	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV
1																					
2													3	38.2	2.97						
3	8	31.2	2.20										2	45.4	2.83						
4																					
5							10	30.6	2.72												
6	6	34.5	5.67	22	28.5	3.80				4	38.4	2.83									
7										30	35.1	3.91				122	37.3	4.06			
8													38	36.4	5.96				17	45.8	3.01
9																19	35.7	2.30			
10							4	31.7	2.17							9	34.1	3.77			
11										4	34.2	2.91									
12							4	32.1	3.08				10	43.2	1.58	39	35.6	4.55			
13							2	23.6	0.21												
14							14	33.6	6.13				2	33.1	2.62						
15							3	33.4	0.72												
16																					
17										4	29.7	4.16				44	36.3	3.43			
18										43	34.6	4.49				46	32.0	7.08			
19							4	31.9	1.35							55	36.2	5.15			
20							8	31.2	5.27												
21																					
22							6	27.3	3.44				1	44.1	-						
23							2	27.1	5.16												

NORTHWESTERN REGION

CON-TRACT	20 MPa			25 MPa			25 MPa SLAG			30 MPa		
	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	#TESTS	MEAN	ST. DEV.	# TESTS	MEAN	ST.DEV
1												
2				2	27.5	0.07				11	38.8	2.56
3										32	30.6	2.40
4	6	38.1	3.67							11	36.8	3.98
5	1	41.2	-							13	34.9	3.99
6	1	35.1	-	12	31.7	3.76				30	33.9	3.52
7										2	37.1	0.71
8				2	28.3	2.19						
9				3	27.9	2.12						
10										1	38.8	-
11				1	29.2	-				30	33.5	5.22
12	3	30.7	2.81									
13	2	26.3	2.69									
14	13	31.8	2.88	22	32.1	2.68						
15							4	33.3	1.88			
16										6	30.9	4.42
17	1	37.8	-									
18										8	35.1	3.18
19	1	23.3	-	2	37.1	4.68				4	38.2	6.32

SUMMARY OF 28-DAY COMPRESSIVE STRENGTH TEST RESULTS

NORTHERN REGION

CON-TRACT	20 MPa			20 MPa SLAG			25 MPa			25 MPa SLAG			30 MPa			30 MPa SLAG			35 MPa SLAG		
	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV
1													28	36.7	4.84						
2				6	29.1	2.59				2	33.0	1.46				12	39.4	6.10			
3							3	30.1	0.89												
4							1	29.2	-				14	37.1	5.74						
5							2	34.6	1.77				36	31.2	5.77						
6							10	33.5	4.99				22	29.9	3.63						
7							4	38.1	5.39				35	37.0	4.12						
8																17	39.7	5.66	24	46.7	4.22
9										2	36.6	2.37				6	38.1	4.69			
10	1	27.5	-				16	32.7	3.52												
11													20	33.7	3.32						
12										1	26.6	-									
13	1	32.1	-																		
14							5	27.8	2.25				4	35.1	3.20						
15							12	29.8	3.17												
16	2	33.5	2.62										7	36.7	3.48						
17	2	38.8	2.16				11	38.7	6.71				18	37.3	4.97						
18							1	32.6	-				7	38.3	4.98						

SUMMARY OF 28-DAY COMPRESSIVE STRENGTH TEST RESULTS

SUMMARY OF CONTRACTS UNDER THE PERFORMANCE SPECIFICATION

CONTRACT NUMBER	30 MPa			35 MPa		
	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV
1	20	41.0	5.3			
2	28	35.1	5.2	33	38.2	3.2
3	14	34.9	3.9	31	37.3	2.4
4	9	40.1	3.7	20	47.6	4.1
5	34	34.6	4.5			
6	37	38.0	5.3			
7	66	40.2	4.5			
8	61	32.9	5.8			
9	29	37.2	4.9			
10	107	38.0	4.5			
11	18	40.8	3.9	12	41.3	2.8
12	3	41.0	4.5			
13	21	38.1	4.9	31	45.7	4.3
14	69	35.1	5.0			